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A comparison of normal and osteoarthritic humeral head size and morphology

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Background: The purpose of this study was to evaluate and to compare the size and morphologic patterns among normal and osteoarthritic (OA) humeral heads.
Methods: This comparative anatomic imaging study evaluated 150 humeral heads that were separated into 3 cohorts: normal, OA with symmetric glenoid erosion, and OA with asymmetric (type B2) glenoid erosion. Three-dimensional models were created of the humeral head from computed tomography data, and point coordinates were extracted for evaluation. Parameters measured were diameter (sphere fit and circle fit), chord distance (superoinferior and anteroposterior), and humeral head height.
Results: The sphere-fit diameter of the humeral head for the entire OA cohort (100 patients; mean diameter, 59 ± 9 mm) was significantly greater ($P < .001$) than that of the normal cohort (50 patients; mean diameter, 49 ± 5 mm). Similarly, the humeral head circle-fit diameters in the superoinferior and anteroposterior planes were significantly greater ($P < .001$) in the combined OA cohorts (59 ± 9 mm and 56 ± 10 mm, respectively) compared with the normal cohort (51 ± 5 mm and 47 ± 5 mm, respectively). However, there were no significant differences ($P \geq .099$) between the symmetric and asymmetric OA cohorts in sphere-fit or circle-fit diameters. The mean values of humeral head heights were not significantly different ($P = .382$) between cohorts, 19 ± 2 mm, 18 ± 2 mm, and 18 ± 2 mm for the normal, symmetric, and asymmetric cohorts, respectively.
Discussion: Although OA humeral head morphology varies significantly from normal, it does not vary as a function of the Walch classification between symmetric and asymmetric glenoids. Understanding of the morphologic variability of the pathologic humeral head may provide insight into the pathoanatomy of osteoarthritis and the development of various erosion patterns.
Level of evidence: Basic Science Study, Anatomy, Imaging.

Keywords: Humeral head; morphology; osteoarthritis; type B2; biconcave; shoulder arthroplasty

Glenohumeral osteoarthritis causes progressive joint damage with extensive bone remodeling and osteophyte formation. As a result, it has been observed that osteoarthritic (OA) humeral heads are morphologically different from normal humeral heads. However, little research has

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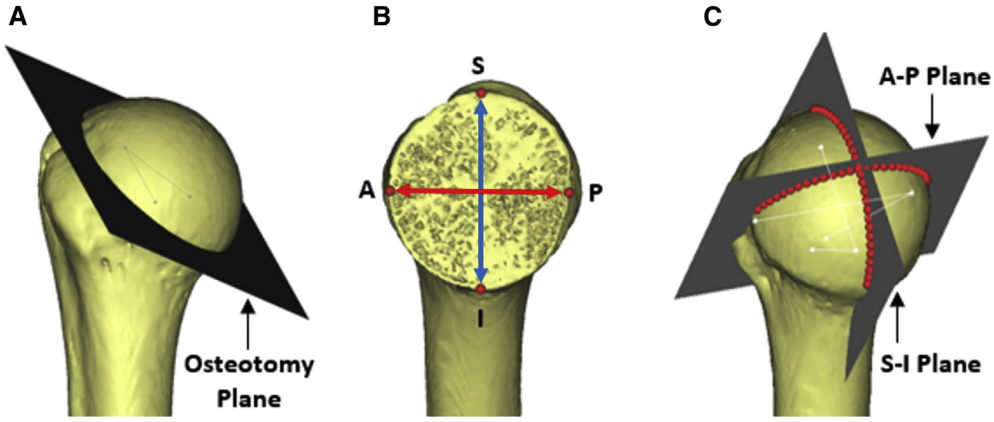

Figure 1 (**A**) The osteotomy plane. (**B**) Superior (S), inferior (I), anterior (A), and posterior (P) points on the humeral head-neck osteotomy plane. The *blue arrow* represents the S-I chord distance, and the *red arrow* represents the A-P chord distance. (**C**) Points on the humeral head used for circle fitting in the S-I and A-P planes.

examined and compared the size and morphology of arthritic humeral heads with normal humeral heads.[22] Conversely, the arthritic glenoid has been well investigated.[19] Characteristic erosion patterns of the arthritic glenoid have been classified,[18] and regional variations in density, shape, orientation, and porosity have been reported.[3,10,11,17]

Although morphologic changes to the humeral head are known to occur,[22] an anatomic characterization of the unique morphology of the OA humeral head is lacking. As such, the purpose of this study was to evaluate and to compare the size and morphology of normal and OA humeral heads. In addition, we subclassified our OA cohort as having symmetric or asymmetric (type B2)[18] glenoid erosion to assess whether humeral head morphology varied by the type of glenoid erosion. We hypothesized that because of erosion, the arthritic humeral head has a larger spherical diameter and is thinner, relative to the osteotomy plane, than normal humeral heads. This information may improve our understanding of glenohumeral pathoanatomy and posterior glenoid erosion patterns and assist with implant design.

Methods

Computed tomography (CT) scans of 150 shoulders were included in this study for anatomic measurements of the humeral head. These scans were subdivided into 3 cohorts: (1) normal shoulders with no signs of fracture, deformity, instability, or arthritis (mean age, 68 $\pm$ 16 years); (2) primary glenohumeral OA with symmetric glenoid erosion (mean age, 68 $\pm$ 10 years); and (3) primary glenohumeral OA with asymmetric (type B2) glenoid erosion (mean age, 63 $\pm$ 10 years). The total OA group was divided into these cohorts to investigate the potential relationship of glenoid erosion pattern with humeral head size and morphology.

Each cohort comprised 50 shoulders (30 male and 20 female) without any paired samples. The normal cohort had 30 left and 20 right shoulders, the symmetric OA cohort had 25 left and 25 right, and the asymmetric (B2) OA cohort had 24 left and 26 right. The normal cohort contained cadaveric shoulder specimens, and the OA cohorts consisted of patients who were scheduled for or had undergone total shoulder arthroplasty at 1 of 2 institutions between 2007 and 2015. These scans were evaluated by 1 of 2 fellowship-trained shoulder surgeons (J.D.K. and G.S.A.) and classified according to the Walch classification for glenoid erosion[18] with use of a clinically relevant method.[13]

Three-dimensional models were created for all shoulders using CT digital imaging and communications in medicine data and medical imaging software (Mimics 17.0; Materialise, Leuven, Belgium) that has been validated for anatomic measurements.[2] Standard segmentation techniques were used to preserve both cancellous and cortical bone.[11] Anatomic measurements were completed by extracting 3-dimensional point coordinates using the software's built-in MedCAD module. Points were extracted and analyzed using custom code to ensure consistency in mathematical analysis (MATLAB; MathWorks, Natick, MA, USA). This method has been previously validated for anatomic measurements in the glenohumeral joint.[2,10] Measurements included in this study to evaluate variations in the size and morphology of the humeral head included sphere-fit diameter of the humeral head articular surface, circle-fit diameter of the humeral head articular surface in the superoinferior plane, circle-fit diameter of the humeral articular surface in the anteroposterior plane, humeral head height relative to the osteotomy plane, and superoinferior and anteroposterior chord distances of the osteotomy surface after excision of the humeral head (Fig. 1).

For surface point acquisition, points were placed on the smooth articular surface of the humeral head.[6] In the OA cohorts, peripheral osteophyte formations were strictly avoided.[10] Points were evenly distributed across the